

To calculate the reasonable maximum exposure for this pathway, 50th percentile values, instead of 95th percentile values, are used for the area of exposed skin (SA). This is because surface area and body weight are strongly correlated and 50th percentile values are most representative of the surface area of individuals of average weight (e.g., 70 kg) which is assumed for this and all other exposure pathways. Estimates of exposure for this pathway are still regarded as conservative because generally conservative assumptions are used to estimate dermal absorption (PC) and exposure frequency and duration.

Consider pathway-specific variations for the intake variables. SA will vary with activity and the extent of clothing worn. For example, a greater skin surface area would be in contact with water during bathing or swimming than when wading. Worker exposure via this pathway will depend on the type of work performed at the site, protective clothing worn, and the extent of water use and contact.

6.6.2 CALCULATE SOIL, SEDIMENT, OR DUST INTAKES

Individuals may be exposed to chemicals of potential concern in soil, sediment, or dust by the following routes:

- (1) incidental ingestion; and
- (2) dermal contact.

Inhalation exposures to airborne soil or dust are discussed in Section 6.6.3.

Incidental ingestion. Calculate intakes from incidental ingestion of chemicals in soil by residents using the equation and variable values presented in Exhibit 6-14. Consider population characteristics that might influence variable values. Exposure duration (ED) may be less for workers and recreational users.

The value suggested for ingestion rate (IR) for children 6 years old and younger are based primarily on fecal tracer studies and account for ingestion of indoor dust as well as outdoor soil. These values should be viewed as representative of long-term average daily ingestion rates for children and should be used in conjunction with an exposure frequency of 365 days/year. A term can be used to account for the fraction of soil or dust contacted that is presumed to be contaminated (FI). In some cases, concentrations in indoor dust can be equal

to those in outdoor soil. Conceivably, in these cases, FI could be equal to 1.0.

For ingestion of chemicals in sediment, use the same equation as that used for ingestion of soil. Unless more pathway-specific values can be found in the open literature, use as default variable values the same values as those used for ingestion of soil. In most instances, contact and ingestion of sediments is not a relevant pathway for industrial/commercial land use (a notable exception to this could be workers repairing docks).

Dermal contact. Calculate exposure from dermal contact with chemicals in soil by residents using the equation and variable values presented in Exhibit 6-15. As was the case with exposure to chemicals in water, calculation of exposure for this pathway results in an estimate of the absorbed dose, not the amount of chemical in contact with the skin (i.e., intake). Absorption factors (ABS) are used to reflect the desorption of the chemical from soil and the absorption of the chemical across the skin and into the blood stream. Consult the open literature for information on chemical-specific absorption factors. In the absence of chemical-specific information, use conservative assumptions to estimate ABS.

Again, as with dermal exposure to water, 50th percentile body surface area (SA) values are used to estimate contact rates. These values are used along with average body weight because of the strong correlation between surface area and body weight. Contact rates may vary with time of year and may be greater for individuals contacting soils in the warmer months of the year when less clothing is worn (and hence, more skin is available for contact). Adherence factors (AF) are available for few soil types and body parts. The literature should be reviewed to derive AF values for other soil types and other body parts. Exposure frequency (EF) is generally determined using site-specific information and professional judgment.

"Best guess" values for children potentially useful in risk assessments are 3 times/week for fall and spring days (>32°F) and 5 times/week for summer days when children are not attending school. As discussed previously, in some cases, concentrations in indoor dust could be equal to that in outdoor environments. Therefore, at some sites, EF could be 365 days/year. Worker and recreational user contact rates are dependent on the type of activity at the site. Exposure duration (ED) and exposure frequency (EF) may be lower for workers and recreational users.

For dermal contact with sediment or dust, use the same equation as that for dermal contact with soil. As default values, also use the variable values given for dermal contact with soil unless more pathway-specific values can be found in the open literature. Adherence factors for some sediments (particularly sandy sediments) are likely to be much less than for soils because contact with water may wash the sediment off the skin. Exposure frequency for sediments also is probably lower than that for soils at many sites.

6.6.3 CALCULATE AIR INTAKES

Individuals may be exposed to chemicals of potential concern in air by inhalation of chemicals in the vapor phase or adsorbed to particulates. Dermal absorption of vapor phase chemicals is considered to be lower than inhalation intakes in many instances and generally is not considered in Superfund exposure assessments.

As with other pathways, the inhalation intakes are expressed in units of mg/kg-day. The combination of inhalation intakes with inhalation RfDs (expressed in concentration units of mg/m³) will be discussed in Chapters 7 and 8.

Inhalation of vapor-phase chemicals . Calculate intakes from inhalation of vapor phase chemicals using the equation and variable values presented in Exhibit 6-16. Consider variations with land use. Exposure time (ET) will generally be less for workers and recreational users. For exposure times less than 24 hours per day, an hourly inhalation rate (IR) based on activity, age, and sex should be used instead of the daily IR values. Exposure duration (ED) may also be less for workers and recreational users.

Inhalation of particulate phase chemicals. Calculate intakes from inhalation of particulate phase chemicals by modifying the equations and variable values

presented in Exhibit 6-16 for vapor-phase exposures. Derive inhalation estimates using the particulate concentration in air, the fraction of the particulate that is respirable (i.e., particles 10 μ m or less in size) and the concentration of the chemical in the respirable fraction. Note that it may be necessary to adjust intakes of particulate phase chemicals if they are to be combined with toxicity values that are based on exposure to the chemical in the vapor phase. This adjustment is done in the risk characterization step.

6.6.4 CALCULATE FOOD INTAKES

Individuals may be exposed by ingestion of chemicals of potential concern that have accumulated in food. The primary food items of concern are:

- (1) fish and shellfish;
- (2) vegetables and other produce; and
- (3) meat, eggs, and dairy products (domestic and game species).

Ingestion of fish and shellfish. Calculate intakes from ingestion of fish and shellfish using the equation and variable values given in Exhibit 6-17. Exposure will depend in part on the availability of suitable fishing areas. The chemical concentration in fish or shellfish (CF) should be the concentration in the edible tissues (when available). The edible tissues will vary with aquatic species and with population eating habits. Residents near major commercial or recreational fisheries or shell fisheries are likely to ingest larger quantities of locally caught fish and shellfish than inland residents. In most instances, workers are not likely to be exposed via this pathway, although at some sites this may be possible.

Ingestion of vegetables or other produce. Calculate intakes from ingestion of contaminated vegetables or other produce using the equation and variable values given in Exhibit 6-18. This pathway will be most significant for farmers and for rural and urban residents consuming homegrown fruits and vegetables. For contaminated backyard gardens, the fraction of food ingested that is contaminated (FI) can be estimated using information on the fraction of fruits or vegetables consumed daily that is home grown (HF). EPA (1989d) provides HF values for fruit (0.20, average; 0.30 worst-case) and vegetables (0.25, average; 0.40,

worst-case). (Worst-case values can be used as estimates of the 95th percentile value.) Pao *et al.* (1982) provides specific values for a variety of fruits and vegetables.

Workers are not likely to be exposed via this pathway. Recreational users could be exposed from consuming wild fruits or vegetables from the site, although such exposures are likely to be negligible.

Ingestion of meat, eggs, and dairy products.

Calculate intakes from ingestion of contaminated meat and dairy products using the equation and variable values given in Exhibit 6-19. Derive pathway-specific values as necessary. Rural residents may consume poultry as well as livestock and wild game that have been exposed to contaminants at the site. The fraction of food ingested daily that is contaminated (FI) can be estimated for beef and dairy products using information provided in EPA (1989d) on the fraction of these foods that is homegrown (HF). HF for beef is estimated to be 0.44 (average) and 0.75 (worst-case). HF for dairy products is estimated to be 0.40 (average) and 0.75 (worst-case). (Worst-case values can be used as estimates of the 95th percentile value.) Consider land-use variations. Workers are not likely to be exposed via this pathway. Exposure duration (ED) and exposure frequency (EF) will likely be less for recreational users (e.g., hunters).

6.7 COMBINING CHEMICAL INTAKES ACROSS PATHWAYS

As discussed previously, the RME at a site reflects the RME for a pathway as well as the RME across pathways. A given population may be exposed to a chemical from several exposure routes. For example, residents may be exposed to chemicals in ground water via ingestion of drinking water and via inhalation of chemicals that have volatilized from ground water during its use. They also could be exposed to chemicals in vapors or dust that have migrated from the site. To calculate an exposure that is a reasonable maximum across pathways, it may be necessary to combine the RME for one pathway with an estimate of more typical exposure for another pathway (see Section 8.3.1). The average variable values identified in the previous sections can be used to calculate intakes for these more typical exposures. At this point in the assessment, estimated intakes are not summed across pathways; this is addressed in the risk characterization chapter. However, the assessor should organize the results of the previous exposure analyses (including any estimates of typical

exposure) by grouping all applicable exposure pathway for each exposed population. This organization will allow risks from appropriate exposures to be combined in the risk characterization chapter (see Exhibit 6-22 for a sample summary format).

6.8 EVALUATING UNCERTAINTY

The discussion of uncertainty is a very important component of the exposure assessment. Based on the sources and degree of uncertainty associated with estimates of exposure, the decision-maker will evaluate whether the exposure estimates are the maximum exposures that can be reasonably expected to occur. Section 8.4 provides a discussion of how the exposure uncertainty analysis is incorporated into the uncertainty analysis for the entire risk assessment.

The discussion of uncertainty in the exposure assessment chapter should be separated into two parts. The first part is a tabular summary of the values used to estimate exposure and the range of these values. The table should include the variables that appear in the exposure equation as well as those used to estimate exposure concentrations (e.g., model variables). A simple example of this table is shown in Exhibit 6-20. For each variable, the table should include the range of possible values, the midpoint of the range (useful values for this part are given in Exhibits 6-11 through 6-19), and the value used to estimate exposure. In addition, a brief description of the selection rationale should be included. The discussion that accompanies the table in the exposure assessment chapter should identify which variables have the greatest range and provide additional justification for the use of values that may be less certain.

The second part of the uncertainty discussion is to summarize the major assumptions of the exposure assessment, to discuss the uncertainty associated with each, and to describe how this uncertainty is expected to affect the estimate of exposure. Sources of uncertainty that should be addressed include 1) the monitoring data, which may or may not be representative of actual conditions at the site; 2) the exposure models, assumptions and input variables used to estimate exposure concentrations; and 3) the values of the intake variables used to calculate intakes. Each of these sources should be discussed in the summary section of the exposure assessment. A table may be useful in summarizing this information. Exhibit 6-21 presents a sample format.

A supplemental approach to uncertainty analysis is to use analytical methods (e.g., first-order uncertainty analysis) or numerical methods (e.g., Monte Carlo analysis). These methods and

their limitations are described in greater detail in Section 8.4. It is recommended that these analyses be used only after approval of the EPA project manager, and then, only as a part of the uncertainty analysis (and not as a basis for the reasonable maximum exposure).

6.9 SUMMARIZING AND PRESENTING THE EXPOSURE ASSESSMENT RESULTS

At this point, the exposure assessor should summarize the results of the exposure assessment. The summary information should be presented in table format and should list the estimated chemical-specific intakes for each pathway. The pathways should be grouped by population so that risks can be combined across pathways as appropriate. The summary information should be further grouped by current and future use categories. Within these categories, subchronic and chronic daily intakes should be summarized separately. Exhibit 6-22 presents a sample format for this summary information.

In addition to the summary table, provide sample calculations for each pathway, to aid in the review of the calculations.

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